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The Effect of Circle and Square Escape Vents on Discard Reduction in the Black Sea Bass, *Centropristis striata*, Trap Fishery

Research Set-A-Side
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I. Title The Effect of Circle and Square Escape Vents on Discard Reduction in the Black Sea Bass, *Centropristis striata*, Trap Fishery

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II. Abstract

Research conducted in 1994 by the Mid-Atlantic Fishery Management Council demonstrated the significant reduction of sub-legal black sea bass caught in traps with rectangular shaped vents compared to un-vented traps, and formed the basis of the mandatory use of a vent in the black sea bass trap fishery. Though a large proportion of black sea bass trap fishermen in the Mid-Atlantic use either circle or square vents, no work has been performed to determine the selectivity of traps using circular or square vents. The current study was designed to evaluate the effectiveness of various vent sizes of both circular and square vent types in reducing discards in the Mid-Atlantic black sea bass trap fishery. Under current management, 2" square and 2 3/8" circle vent sizes are required to select out the minimum legal size black sea bass of 11" (28cm). One hundred and fifty traditional wire mesh traps of uniform design using varying escape vent openings for both circle (2 1/4", 2 3/8", 2 1/2", and 2 5/8" in diameter) and square (1 7/8", 2", 2 1/8", and 2 1/4" square inside measurements) design were fished from June to December 2002. Escape vents significantly ($p<0.001$) reduced the amount of sub-legal sea bass caught relative to un-vented (control) traps, achieving reductions of 9.5-28.8% in square vents and 11.5-36.3% in circle vents tested. Total catch and number of sub-legal sea bass decreased, as escape vent size increased in both circular and square escape vent designs, while mean length of fish increased. The catch of legal sized sea bass increased as vent size increased, up to a point; it leveled off at the 2 ¼" square and 2 5/8" circle vent sizes relative to other vents within its shape series. In general, circular escape vents caught more sea bass relative to the square vents. However, examinations of size selectivity (proportion of fish retained and length frequency distributions) indicate that any given circle vent tested resulted in selection of smaller fish than that of its corresponding square vent.

III. Executive Summary

The Mid-Atlantic Fishery Management (MAFMC) Council Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan (FMP) were enacted in 1996, which implemented new management measures for black sea bass trap fishermen. The FMP initiated the Councils fishing mortality rate reduction strategy that would allow for stock rebuilding. As part of this FMP, the use of a single escape vent in each trap was mandated. The uses of cull rings and escape panels, or vents, to facilitate escapement of undersize animals within trap fisheries is well documented, however, information specific to black sea bass was lacking. Research conducted by MAFMC specific for the sea bass trap fishery, which formed the basis of the FMP vent policy, demonstrated the significant reduction of sub-legal bass caught in traps with a vent (MAFMC 1996). This study tested various sizes of rectangular vents. No work was performed to determine the selectivity of traps using circular or square vents, though a large proportion of black sea bass trap fishermen in the Mid-Atlantic use either circle or square vents. Proposed, then mandated, dimensions for a circular and square vent were derived from black sea bass body length/depth relationships. Research on the effectiveness of size selectivity between different vent designs widely used throughout the industry was needed to address mortality in the black sea bass trap fishery and enable MAFMC to make sound management recommendations.

The overall objective of this project was to evaluate the effectiveness of various sizes of escape vents, of both circular and square vent designs, in reducing discards as part of the black sea bass FMP fishing mortality rate reduction strategy. Project objectives included: 1) determine the size selectivity of each black sea bass trap vent size tested relative to un-vented traps; 2) determine relative differences in fish size selectivity between circle and square vent types; and 3) to observe related discard mortality from hauled traps to obtain practical information to assist with future potential research objectives.

One hundred and fifty traditional wire mesh traps were constructed or modified for use in this study. Traps were of uniform design: single funnel 36" x 21" x 14" rectangular traps made from vinyl coated 1 1/2" mesh 14 gauge wire, with a ghost panel located in the parlor section of trap fixed with degradable fasteners. Thirty traps served as controls (no vent), 60 traps fitted with circle vents and 60 traps fitted with square vents. Four vent sizes were evaluated within both vent types, which bracketed the current legal size to accommodate future minimum size restrictions. Circle vent sizes evaluated included 2 1/4", 2 3/8", 2 1/2", and 2 5/8" in diameter. Square vent sizes evaluated included 1 7/8", 2", 2 1/8", and 2 1/4" square inside measurements. Current regulations require the use of either a 2" square or 2 3/8" circular vent to select for the minimum size sea bass of 11". Fishing occurred from 25 to 55 miles off the coast of Virginia Beach, VA at fishing depths ranging from 24 to 36 meters. The study employed a randomized block design of five traps per block (control and the four vent sizes) for both circle and square vent designs.

A total of 2,080 trap hauls were made over 16 trips from June 24, 2002 through December 31, 2002. Total number of black sea bass captured was 30,462, with a combined weight of 10,428.69 kg. Catches varied temporally with times of peak catch rates occurring in November and December and lowest catch rates occurring during July and October. Results of the ANOVA indicated significant differences ($p<0.0001$) between vent configurations for each of the size groups tested. The total number of fish caught decreased with increasing vent size, but the catch of legal sized sea bass (>28cm) increased as vent size increased. As expected, escape vents significantly ($p<0.001$) reduced the amount of sub-legal sea bass caught relative to un-vented (control) traps, achieving reductions of 9.5-28.8% in square vents and 11.5-36.3% in circle vents tested. In general, the mean catch from the larger vent sizes in each shape was significantly different ($p<0.0001$) from the smaller vent sizes regardless of shape. The catch of sub-legal sea bass (<28cm) decreased as escape vent size increased. The percent of undersized fish per trap decreased as vent size increased in both circular and square escape vents. Comparisons observed between vent shapes indicate circular escape vents catch more sea bass relative to the square vents, however, relative selectivity of circle vents was for smaller fish than that of its corresponding square vent. Fish size selectivity for the legal 2" square vent was between 27 and 28 cm, and between 25 and 27 cm for the legal 2 3/8" circular vent.

IV. Purpose

A. In the early 1990s stock assessments for black sea bass, *Centropristis striata*, indicated that stocks were becoming over exploited. Amendment 9 to the Mid-Atlantic Fishery Management (MAFMC) Council Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan (FMP) was enacted in 1996 which implemented new management measures for black sea bass trap fishermen north of Cape Hatteras, NC which included minimum fish size and the use of an escape vent (MAFMC 1996). The basis for these measures was to initiate a fishing mortality rate reduction strategy that would allow for stock rebuilding. Estimates on commercial black sea bass discard

Prior to Amendment 9, most black sea bass traps were fished without an escape vent. The uses of cull rings and escape panels, or vents, to facilitate escapement of undersize animals within trap fisheries is well documented, however, information specific to black sea bass was lacking. Research conducted by MAFMC specific for the sea bass trap fishery, which formed the basis of Amendment 9 vent policy, demonstrated the significant reduction of sub-legal bass caught in traps with a vent (MAFMC 1996). This study tested various sizes of rectangular vents. No work was performed to determine the selectivity of traps using circular or square vents, though a large proportion of black sea bass trap fishermen in the mid-Atlantic use either circle or square vents. Proposed, then mandated, dimensions for a circular and square vent were derived from black sea bass body length/depth relationships (Weber and Briggs 1983).

The implementation of an escape vent within the trap allows for the release of undersize fish while on the bottom and/or during initial stage of haul-back, before the damaging affects of pressure changes are experienced. In 2002, the MAFMC approved fishery management measures, which in part, include the increase in minimum fish size from 10" to 11", and vent sizes of 2 3/8" circular, 2" square, and 1 3/8" x 5 3/4" rectangular. Until this work, no research had been conducted in the black sea bass fishery on the circle and square trap vents. Research as to the effectiveness of size selectivity between different vent designs widely used throughout industry is needed to address mortality in the black sea bass trap fishery and enable MAFMC to make sound management recommendations. The current study was designed to evaluate the effectiveness of various vent sizes of both circular and square vent types in reducing discards in the Mid-Atlantic black sea bass trap fishery.

B. The overall objective of this project was to evaluate the effectiveness of various sizes of escape vents, of both circular and square vent designs, in reducing discards as part of the black sea bass FMP fishing mortality rate reduction strategy. Project objectives included: 1) determine the size selectivity of each black sea bass trap vent size tested relative to un-vented traps; 2) determine relative differences in fish size selectivity between circle and square vent types; 3) determine relative technical efficiency between vent types in context of legal fish retained on basis of effort; and 4) to observe related discard mortality from hauled traps to obtain practical information to assist with future potential research objectives.

V. Approach

A. The project entailed the testing of two different vent types of various sizes to quantify fish size selectivity. One hundred and fifty traditional wire mesh traps were constructed or modified for use in this study. Traps were of uniform design: single funnel 36" x 21" x 14" rectangular traps made from vinyl coated 1 1/2" mesh 14 gauge wire, with a ghost panel located in the parlor section of trap fixed with degradable fasteners (Figure 1). Thirty traps served as controls (no vent), 60 traps fitted with circle vents and 60 traps fitted with square vents. Four vent sizes were evaluated within both vent types, which bracketed the current legal size to accommodate future minimum size restrictions. Circle vent sizes evaluated included 2 1/4", 2 3/8", 2 1/2", and 2 5/8" in diameter. Square vent sizes evaluated included 1 7/8", 2", 2 1/8", and 2 1/4" square inside measurements. Based on research conducted on optimal positioning of vents to maximize fish escapement (Shepherd et al, 2002), all vents were placed in a side panel of traps parlor near the bottom.

Fishing occurred from June through December 2002, 25 to 55 miles offshore between Currituck Light, North Carolina and Hog Island, Virginia at fishing depths ranging from 24 to 36 meters. The study employed a randomized block design of five traps per block (control and the four vent sizes) for both circle and square vent designs. The blocks were fished in strings (trawl lines) consisting of four blocks per string, with blocks of circle vented traps randomly alternated within the string with blocks of square vented traps. Thereby, each string consisted of 4 blocks totaling 20 traps. Individual traps within a block and along the string were fixed to a mainline 10 meters apart. Each string was fished in relation to bottom structure, typically a specific hang. Six to eight strings of traps were fished per trip. Soak times for each set of strings ranged from 7 to 21 days, largely dictated by weather conditions. All black sea bass caught were measured to nearest half centimeter. All by-catch caught were quantified by species.

Null hypotheses:

1. vent size had no significant effect on mean length of black sea bass caught in trap.
2. vent shape had no significant effect on mean length of black seas bass caught in trap.

Catch rate was calculated as the number of fish captured per trap divided by the total number of whole days the trap had been fishing. Catch rate data were transformed prior to analysis of variance using $\ln(x+1)$ to correct for non-normality and heterogeneity of variance (Underwood, 1997). An ANOVA was used to test the null hypothesis and a Tukey's test ($\alpha=0.05$) was used to compare mean catch rates between each vent configuration.

Total catches, in both numbers and weight, were compared between vent configurations. The weight of black sea bass was calculated from lengths obtained in the field by using the length-weight equation from Wigley *et al*, 2003:

$$\ln W = \ln a + b * \ln L *$$

where W=weight (kg), L=length (cm), a=y intercept and b=slope
a=-11.4782, b=3.0743

For the examination of selectivity, both length frequency distributions and proportion retained were used. The proportion retained by each vent configuration relative to the un-vent trap was calculated to assess ability of sea bass to escape the traps as a function of fish length. Proportion retained was calculated by the formula:

$$\text{Catch}_{\text{experimental}}/(\text{Catch}_{\text{experimental}} + \text{Catch}_{\text{control}})$$

Where Catch $_{\text{experimental}}$ is the catch (in numbers) of sea bass at a given length interval and Catch $_{\text{control}}$ is the catch (in numbers) of sea bass at the same length interval.

B. This project was a cooperative effort between Virginia commercial sea bass trap fishery permit holders, Mr. Jack Stallings and Mr. Harry Doernte, and Virginia Sea Grant Marine Advisory Program (VSGMAP), Virginia Institute of Marine Science (VIMS), College of William and Mary. The project was managed by Mr. Robert Fisher (VSGMAP Commercial Fisheries Specialist at VIMS). The work was performed on, and with the crew of, the F/V *Grumpy* (Permit # 251528) captained by Mr. Stallings, out of Virginia Beach, VA. All fishing and data collection took place with a research scientist on board, which included Fisher, Mr. David Rudders and/or Mr. Roy Pemberton, all from VIMS.

VI. Findings

A. A total of 2,080 trap hauls were made over 16 trips from June 24, 2002 through December 31, 2002. Total number of black sea bass captured was 30,462, with a combined weight of 10,428.69 kg. The total number and mean number per trap of sea bass captured for each trip and escape vent configuration area shown in tables 1 and 2. Total weight and mean weight per trap of sea bass captured for each trip and escape vent configuration area shown in tables 3 and 4. Individual lengths ranged from 13.5 cm to 58.5 cm total length and weights ranged from 0.031 kg to 2.80 kg per fish. Catches varied temporally with times of peak catch rates occurring in November and December and lowest catch rates occurring during July and October. It is important to note that different numbers of traps were hauled on individual trips therefore standardized measures of number per trap and kg per trap provides a more comparable metric.

Comparisons of standardized catch per trap for legal, sub-legal and total fish are shown in tables 5-10. Results of the ANOVA indicated significant differences ($p<0.0001$) between vent configurations for each of the size groups tested. Comparisons of mean catches among vent configurations for all size classes of sea bass indicate significantly different ($p<0.0001$) catches between many of the vent configurations (table 6). When examined in relation to the current minimum legal size of black sea bass, the mean catches of sub-legal sea bass (<28 cm) were significantly different ($p<0.0001$) between many of the vent configurations (table 8). As expected, the catches from control traps (no vent) were significantly different ($p<0.0001$) from all other vent configurations except the smallest circle vent (2 ¼"). In general, the mean catch from the larger vent sizes in each shape was significantly different ($p<0.0001$) from the smaller vent sizes regardless of shape. Mean catches of legal sea bass (>28 cm) showed fewer significant differences ($p<0.0001$) relative to the sub-legal group (table 10). For the legal fish, catches from the control trap were significantly different ($p<0.0001$) from all other vent configurations except square 1 7/8"and square 2 ¼". The only other significant differences in catches of legal sized fish were between the square 2 ¼" and both circle 2 3/8" and circle 2 ½".

Catches of both legal and sub-legal are shown in figures 2 and 3. The catch of legal sized sea bass increases as vent size increases up to a point where it levels off at the 2 ¼" square and 2 5/8" circle vent sizes relative to other vents within its shape series (fig. 1). In general, circular escape vents caught more legal sized sea bass relative to the square vents. The catch of sub-legal sea bass decreased as escape vent size increased (fig. 3). The percentage of the catch (by numbers) that was comprised of sub-legal fish for each escape vent configuration is shown in figure 4. The percent of undersized fish decreases as vent size increases in both circular and square escape vents.

Length frequency distributions for each escape vent configuration compared with the length frequencies from control traps are shown in figures 5 and 6. As escape vent size increases, so does the size of fish retained in the trap. Hence, larger fish are able to escape from the traps equipped with larger escape vents. Smaller fish, that are able to egress the traps do remain and are captured. This pattern is consistent through all vent sizes and both vent shapes. Size selectivity for any given circle vent is smaller than that of its corresponding square vent. The length frequency of fish captured in traps equipped with 2.0" square and 2 3/8" circle escape vents are shown in figure 7. These two escape vents represent the currently mandated escape vent sizes. Results indicate that of the two, the trap with the 2 3/8" circle escape vent captures more sea bass across the spectrum of lengths encountered, but selectivity is for a smaller fish size.

The proportion retained by each escape vent configuration relative to the control trap is shown in figures 8 and 9. The horizontal reference line represents the level of catch where the experimental and control gears fished equally with respect to the number of fish captured. If the curve falls above the reference line, a gain in catch was realized by using the trap with an escape vent relative to a un-vent trap. Conversely, if the curve falls below the line, a loss in catch was realized by the vented trap relative to the un-vented trap. Values at both large and small lengths may be artificial due to small sample sizes at those lengths. The vertical reference line represents the current minimum legal size for black sea bass. Gains were realized for all escape vent configurations for legal sized fish relative to the control traps. Only the square 2 1/8", square 2 ¼" and the circle 2 5/8" escape vents realized a loss of some legal sized fish at smaller lengths. Though circle vented traps were observed to catch more fish over all traps combined, fish length at point of gain in proportion of fish retained was consistently less than that of corresponding square vented traps. A gain in catch for the current legal size 2" square vented traps was attained at fish length between 27 and 28 cm, while gain in the corresponding 2 3/8" circle vented traps was attained between 25 and 27 cm. As expected, escape vents resulted in substantial reductions in the capture of sub-legal sea bass. The experimental gears captured small fish (18cm-23cm) in numbers that approached levels recorded for the control.

Finfish and invertebrate by-catch encountered during this study is shown in table 11. The Jonah crab, *Cancer borealis*, and an unclassified octopus species dominated the invertebrate by-catch. The conger eel (*Conger oceanicus*), tautog (*Tautoga onitis*), scup (*Stenotomus chrysops*), and gray triggerfish (*Balistes capriscus*) were the dominant finfish by-catch species.

B. The retention of very small fish, ones that could move freely through the 1 ½ "mesh of all traps and escape, posed problems in statistical evaluations, especially with relative selectivity determinations. It was observed that small fish were being retained just inside the trap funnel and in the un-vented "kitchen" part of trap. Further, during periods of juvenile fish residence on structure within our fishing sites (November and December) the capture of these small bass was inflated. The capture of small fish that use the traps for shelter, or social interaction, and freely move in and out of the traps during soak periods was expected, but not to the degree incurred.

C. Though the escapement of targeted sub-legal fish can be attained to some degree by the use of a single vent within a trap, efficiency of escapement can theoretically be increased by the use of two or more vents per trap. It was routinely observed during this research that once the vent was blocked, by a near-legal sea bass or by-catch species trying to escape, further escapement of sub-legal fish was prevented. The use of multiple vents within the parlor section of the trap, and possibly one additional vent in the kitchen section of the trap, could potentially enhance the effectiveness of sea bass escapement in vented traps.

VII. Evaluation

A. The multiple objectives of this research were attained. The objective of generating data on the use of the most widely used vent designs in the Mid-Atlantic as to fish size selectivity for varying vent sizes was met, and provides technical support for black sea bass management decisions. Relative differences between circle and square vent types were documented, and observed discard mortality provided for practical recommendations for future research objectives.

B. Dissemination of project results of this study will be via an industry technical report(s) and submission to an appropriate peer reviewed journal.

Figure 1. Commercial black sea bass wire trap used in the research. Only vent size and shape were varied as per research protocol. Trap entrance funnel on left (kitchen section) and fish holding section (parlor section) with vent on right.

Table 1
Total number of black sea bass captured by trip and escape vent configuration

Trip	# of strings	Control Square	Square 1 7/8"	Square 2"	Square 2 1/8"	Square 2 ¼"	Control Circle	Circle 2 ¼"	Circle 2 3/8"	Circle 2 ½"	Circle 2 5/8"	Total
		# of Fish	# of Fish	# of Fish	# of Fish	# of Fish	# of Fish	# of Fish	# of Fish	# of Fish	# of Fish	# of Fish
6/24/2002	1	26	30	12	34	7	22	35	7	10	31	214
6/29/2002	5	156	127	127	77	61	100	172	113	75	64	1072
7/16/2002	6	111	87	68	44	38	98	138	111	74	58	827
8/3/2002	6	201	177	161	99	92	146	183	126	122	97	1404
8/14/2002	7	249	246	208	162	146	267	236	246	192	176	2128
8/26/2002	7	177	144	138	128	86	180	222	226	122	111	1534
9/6/2002	7	120	171	114	92	87	164	219	189	132	133	1421
9/19/2002	7	244	245	161	171	119	252	262	301	252	216	2223
9/30/2002	8	259	319	207	180	141	293	282	253	182	189	2305
10/25/2002	7	152	217	187	143	112	167	207	201	175	115	1676
11/4/2002	7	121	138	107	159	117	131	113	146	77	119	1228
11/20/2002	8	613	513	308	437	391	523	576	377	354	395	4487
12/7/2002	9	467	391	431	320	314	579	394	366	387	350	3999
12/13/2002	2	58	42	41	48	55	69	47	97	50	48	555
12/19/2002	8	349	172	216	157	155	337	258	189	249	160	2242
12/30/2002	9	315	298	247	290	299	367	393	343	355	240	3147
Total	104	3618	3317	2733	2541	2220	3695	3737	3291	2808	2502	30462

Table 2
Mean number of black sea bass captured per trap by trip and escape vent configuration

Trip	# of strings	Control Square	Square 1 7/8"	Square 2"	Square 2 1/8"	Square 2 ¼"	Control Circle	Circle 2 ¼"	Circle 2 3/8"	Circle 2 ½"	Circle 2 5/8"	Mean
		#/trap	#/trap	#/trap	#/trap	#/trap	#/trap	#/trap	#/trap	#/trap	#/trap	#/trap
6/24/2002	1	13.00	15.00	6.00	17.00	3.50	11.00	17.50	3.50	5.00	15.50	10.70
6/29/2002	5	15.60	12.70	12.70	7.70	6.10	10.00	17.20	11.30	7.50	6.40	10.72
7/16/2002	6	9.25	7.25	5.67	3.67	3.17	8.17	11.50	9.25	6.17	4.83	6.89
8/3/2002	6	16.75	14.75	13.42	8.25	7.67	12.17	15.25	10.50	10.17	8.08	11.70
8/14/2002	7	17.79	17.57	14.86	11.57	10.43	19.07	16.86	17.57	13.71	12.57	15.20
8/26/2002	7	12.64	10.29	9.86	9.14	6.14	12.86	15.86	16.14	8.71	7.93	10.95
9/6/2002	7	8.57	12.21	8.14	6.57	6.21	11.71	15.64	13.50	9.43	9.50	10.15
9/19/2002	7	17.43	17.50	11.50	12.21	8.50	18.00	18.71	21.50	18.00	15.43	15.88
9/30/2002	8	16.19	19.94	12.94	11.25	8.81	18.31	17.63	15.81	11.38	11.81	14.40
10/25/2002	7	10.86	15.50	13.36	10.21	8.00	11.93	14.79	14.36	12.50	8.21	11.97
11/4/2002	7	8.64	9.86	7.64	11.36	8.36	9.36	8.07	10.43	5.50	8.50	8.77
11/20/2002	8	38.31	32.06	19.25	27.31	24.44	32.69	36.00	23.56	22.13	24.69	28.04
12/7/2002	9	25.94	21.72	23.94	17.78	17.44	32.17	21.89	20.33	21.50	19.44	22.21
12/13/2002	2	14.50	10.50	10.25	12.00	13.75	17.25	11.75	24.25	12.50	12.00	13.87
12/19/2002	8	21.81	10.75	13.50	9.81	9.69	21.06	16.13	11.81	15.56	10.00	14.01
12/30/2002	9	17.50	16.56	13.72	16.11	16.61	20.39	21.83	19.06	19.72	13.33	17.48
Mean		17.39	15.94	13.13	12.21	10.67	17.76	17.96	15.82	13.50	12.02	14.65

Table 3
Total kilograms of black sea bass captured by trip and escape vent configuration

Trip	# of strings	Control Square	Square 1 7/8"	Square 2"	Square 2 1/8"	Square 2 ¼"	Control Circle	Circle 2 ¼"	Circle 2 3/8"	Circle 2 ½"	Circle 2 5/8"	Total
		kg.	kg.	kg.	kg.	kg.	kg.	kg.	kg.	kg.	kg.	kg.
6/24/2002	1	11.74	13.52	6.17	22.80	3.48	13.66	15.38	5.36	2.74	12.27	107.12
6/29/2002	5	43.99	45.33	50.46	42.01	36.83	25.09	59.46	42.13	34.20	26.50	406.01
7/16/2002	6	29.18	26.16	28.59	21.67	21.71	30.01	39.42	41.46	32.85	27.75	298.79
8/3/2002	6	63.40	59.53	72.12	48.58	47.45	52.95	63.43	55.15	55.41	45.59	563.63
8/14/2002	7	78.52	92.09	78.40	72.64	63.51	98.64	84.59	102.43	98.19	96.53	865.53
8/26/2002	7	53.21	45.45	48.58	52.08	40.70	54.52	79.02	81.77	48.10	53.59	557.01
9/6/2002	7	41.42	62.09	51.37	49.57	43.44	56.21	75.43	68.51	63.49	66.55	578.07
9/19/2002	7	83.50	90.14	69.86	78.99	73.99	84.69	96.10	118.67	116.21	100.37	912.52
9/30/2002	8	90.43	99.31	72.23	82.50	75.85	87.06	92.95	98.48	77.71	87.70	864.22
10/25/2002	7	49.91	68.31	67.52	64.23	57.23	55.72	70.14	75.22	71.69	52.11	632.08
11/4/2002	7	32.98	44.85	32.73	41.02	38.79	32.05	33.15	48.03	26.03	48.78	378.40
11/20/2002	8	139.86	115.81	81.78	117.10	113.96	120.77	149.40	109.33	103.43	108.92	1160.35
12/7/2002	9	115.95	98.04	114.63	98.15	100.17	131.59	110.22	113.12	120.27	106.33	1108.47
12/13/2002	2	16.53	13.21	13.62	16.10	27.02	17.49	18.00	27.50	14.74	16.98	181.19
12/19/2002	8	86.86	60.08	90.37	57.73	63.14	90.80	83.93	73.06	94.66	70.52	771.16
12/30/2002	9	89.17	101.99	94.81	95.44	110.61	103.60	125.78	111.64	127.30	83.81	1044.14
Total	104	1026.63	1035.90	973.26	960.60	917.87	1054.84	1196.40	1171.86	1087.03	1004.30	10428.69

Table 4
Mean kilograms of black sea bass captured per trap by trip and escape vent configuration

Trip	# of strings	Control Square	Square 1 7/8"	Square 2"	Square 2 1/8"	Square 2 ¼"	Control Circle	Circle 2 ¼"	Circle 2 3/8"	Circle 2 ½"	Circle 2 5/8"	Mean
		kg./trap	kg./trap	kg./trap	kg./trap	kg./trap	kg./trap	kg./trap	kg./trap	kg./trap	kg./trap	kg./trap
6/24/2002	1	5.87	6.76	3.08	11.40	1.74	6.83	7.69	2.68	1.37	6.13	5.35
6/29/2002	5	4.40	4.53	5.05	4.20	3.68	2.51	5.95	4.21	3.42	2.65	4.06
7/16/2002	6	2.43	2.18	2.38	1.81	1.81	2.50	3.28	3.46	2.74	2.31	2.48
8/3/2002	6	5.28	4.96	6.01	4.05	3.95	4.41	5.29	4.60	4.62	3.80	4.69
8/14/2002	7	5.61	6.58	5.60	5.19	4.54	7.05	6.04	7.32	7.01	6.90	6.18
8/26/2002	7	3.80	3.25	3.47	3.72	2.91	3.89	5.64	5.84	3.44	3.83	3.97
9/6/2002	7	2.96	4.43	3.67	3.54	3.10	4.01	5.39	4.89	4.54	4.75	4.12
9/19/2002	7	5.96	6.44	4.99	5.64	5.28	6.05	6.86	8.48	8.30	7.17	6.51
9/30/2002	8	5.65	6.21	4.51	5.16	4.74	5.44	5.81	6.16	4.86	5.48	5.40
10/25/2002	7	3.56	4.88	4.82	4.59	4.09	3.98	5.01	5.37	5.12	3.72	4.51
11/4/2002	7	2.36	3.20	2.34	2.93	2.77	2.29	2.37	3.43	1.86	3.48	2.70
11/20/2002	8	8.74	7.24	5.11	7.32	7.12	7.55	9.34	6.83	6.46	6.81	7.25
12/7/2002	9	6.44	5.45	6.37	5.45	5.56	7.31	6.12	6.28	6.68	5.91	6.15
12/13/2002	2	4.13	3.30	3.41	4.02	6.76	4.37	4.50	6.87	3.69	4.25	4.52
12/19/2002	8	5.43	3.76	5.65	3.61	3.95	5.67	5.25	4.57	5.92	4.41	4.81
12/30/2002	9	4.95	5.67	5.27	5.30	6.14	5.76	6.99	6.20	7.07	4.66	5.80
Mean		4.93	4.98	4.67	4.61	4.41	5.07	5.75	5.63	5.22	4.82	5.01

Table 5
Results of analysis of variance testing for differences in the mean catch per trap of black sea bass in traps with different escape vent configurations.

Source	Degrees of freedom	MS	F	Pr>F
Vent configuration	8	1.738	12.98	<0.001
Error	2071	0.134		
Total	2079			

Table 6
Comparison of mean catch per trap of black sea bass for all escape vent configurations. X indicates a significant difference.

	Control	Square 1 7/8"	Square 2"	Square 2 1/8"	Square 2 1/4"	Circle 2 1/4"	Circle 2 3/8"	Circle 2 1/2"
Square 1 7/8"								
Square 2"	X							
Square 2 1/8"	X	X						
Square 2 1/4"	X	X						
Circle 2 1/4"			X	X	X			
Circle 2 3/8"				X	X			
Circle 2 1/2"	X					X		
Circle 2 5/8"	X	X				X	X	

Table 7
Results of analysis of variance testing for differences in the mean catch per trap of sub-legal (less than 28 cm total length) black sea bass in traps with different escape vent configurations.

Source	Degrees of freedom	MS	F	Pr>F
Vent configuration	8	4.459	47.53	<0.001
Error	2071	0.0938		
Total	2079			

Table 8
Comparison of mean catch per trap of sub-legal (less than 28 cm total length) black sea bass for all escape vent configurations. X indicates a significant difference.

	Control	Square 1 7/8"	Square 2"	Square 2 1/8"	Square 2 1/4"	Circle 2 1/4"	Circle 2 3/8"	Circle 2 1/2"
Square 1 7/8"	X							
Square 2"	X	X						
Square 2 1/8"	X	X						
Square 2 1/4"	X	X	X					
Circle 2 1/4"			X	X	X			
Circle 2 3/8"	X			X	X	X		
Circle 2 1/2"	X	X				X	X	
Circle 2 5/8"	X	X	X			X	X	

Table 9
Results of analysis of variance testing for differences in the mean catch per trap of legal (greater than 28 cm total length) black sea bass in traps with different escape vent configurations.

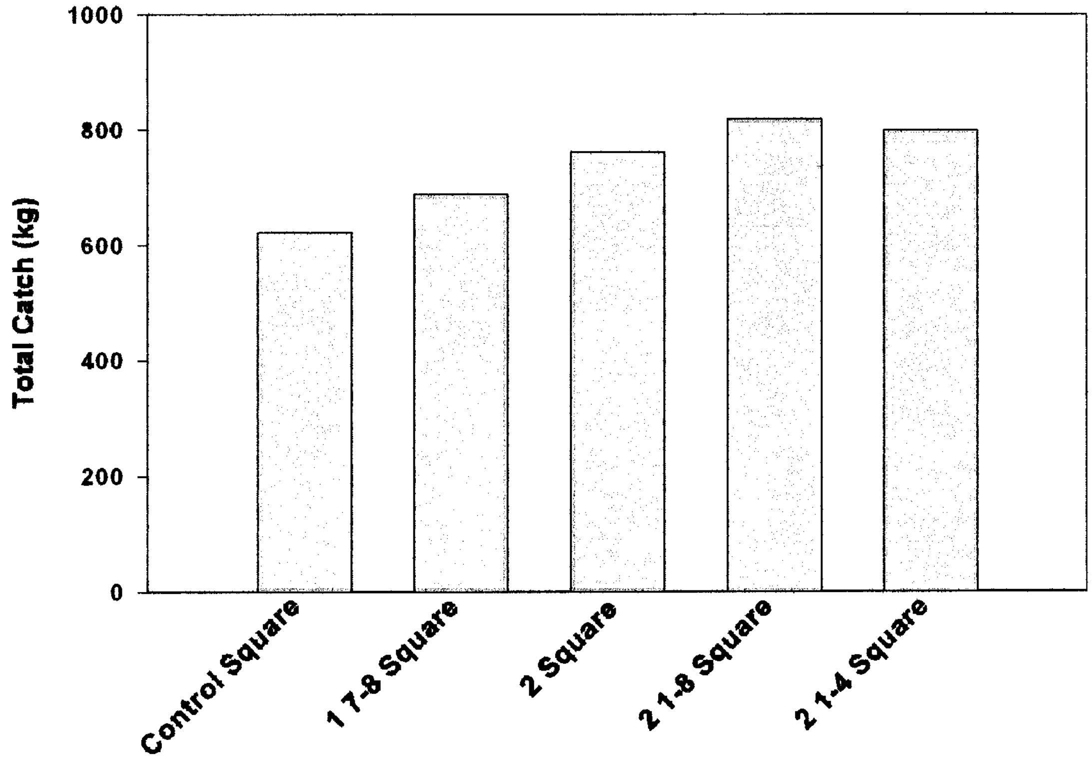
Source	Degrees of freedom	MS	F	Pr>F
Vent configuration	8	0.4865	6.98	<0.001
Error	2071	0.0697		
Total	2079			

Table 10
Comparison of mean catch per trap of legal (greater than 28 cm total length) black sea bass for all escape vent configurations. X indicates a significant difference.

	Control	Square 1 7/8"	Square 2"	Square 2 1/8"	Square 2 1/4"	Circle 2 1/4"	Circle 2 3/8"	Circle 2 1/2"
Square 1 7/8"								
Square 2"	X							
Square 2 1/8"	X							
Square 2 1/4"								
Circle 2 1/4"	X							
Circle 2 3/8"	X				X			
Circle 2 1/2"	X				X			
Circle 2 5/8"	X							

Figure 2

Total catch (by weight) of legal (greater than 28 cm total length) black sea bass in traps with varying shapes and sizes of escape vents


1000
800
600
400
200
0
Total Catch (kg)
Control Square
1 7-8 Square
2 Square
2 1-8 Square
2 1-4 Square

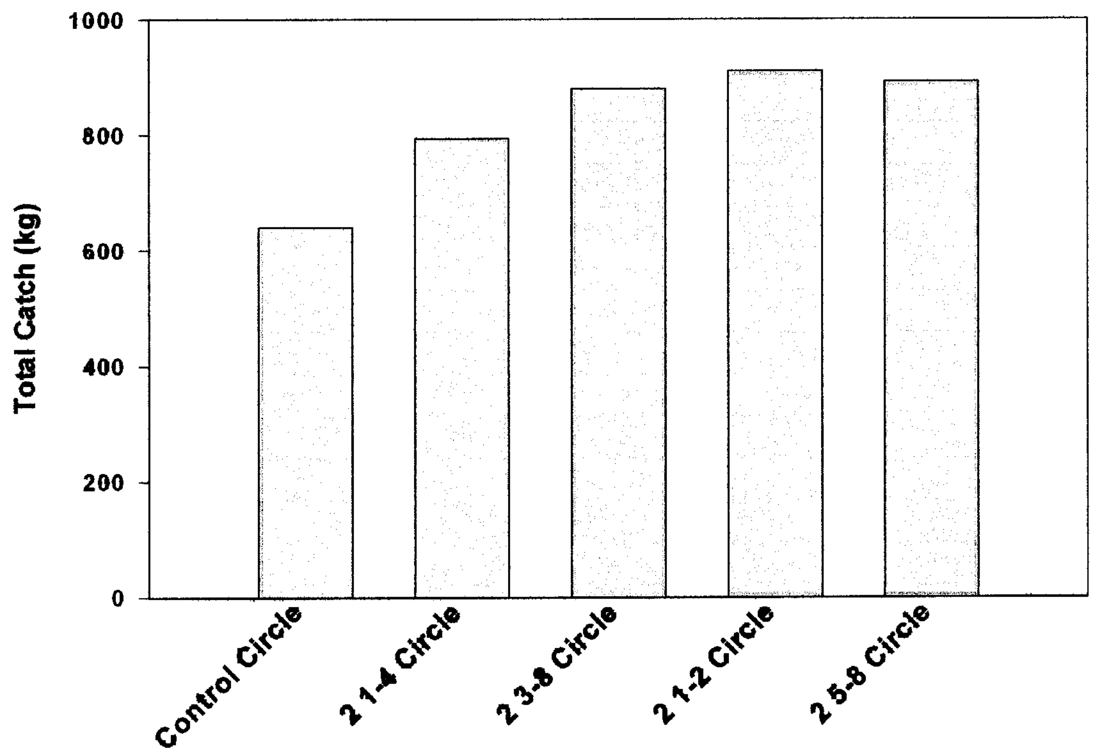
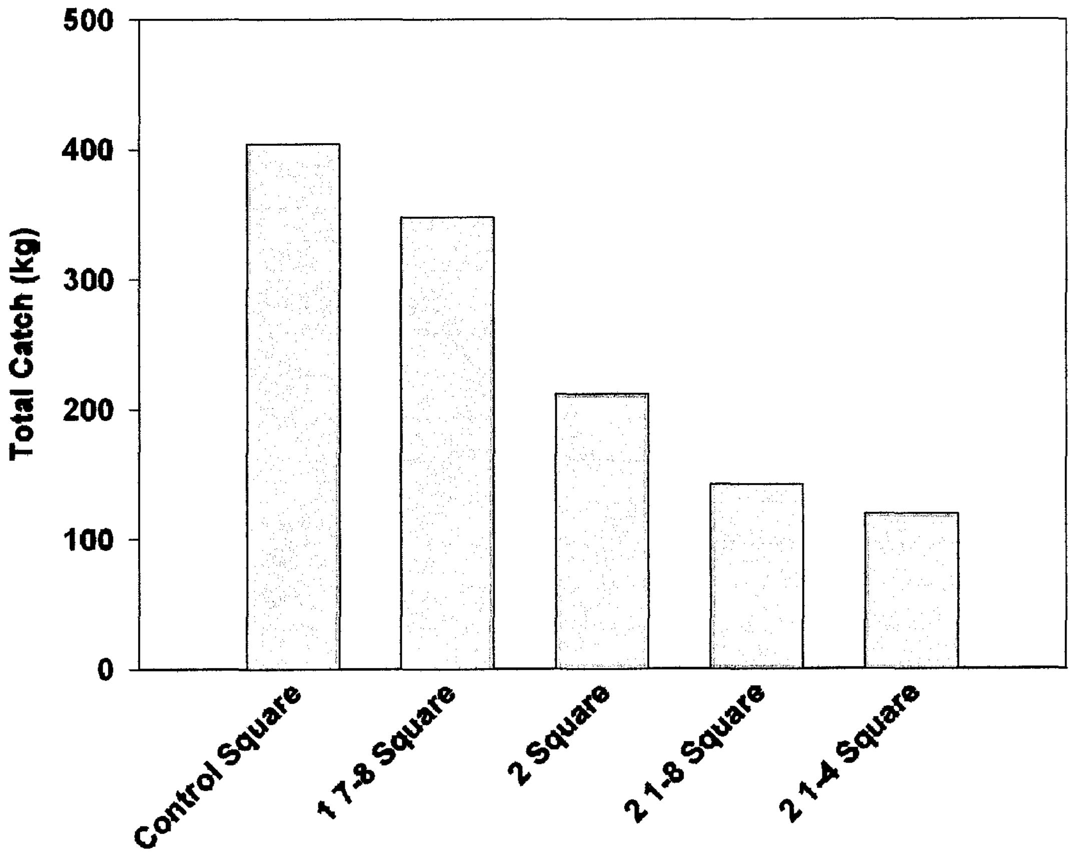

1000
800
600
400
200
0
Total Catch (kg)
Control Circle
2 1-4 Circle
2 3-8 Circle
2 1-2 Circle
2 5-8 Circle

Figure 3

Total catch (by weight) of sub-legal (less than 28 cm total length) black sea bass in traps with varying shapes and sizes of escape vents


500
400
300
200
100
0
Total Catch (kg)
Control Square
1 7-8 Square
2 Square
2 1-8 Square
2 1-4 Square

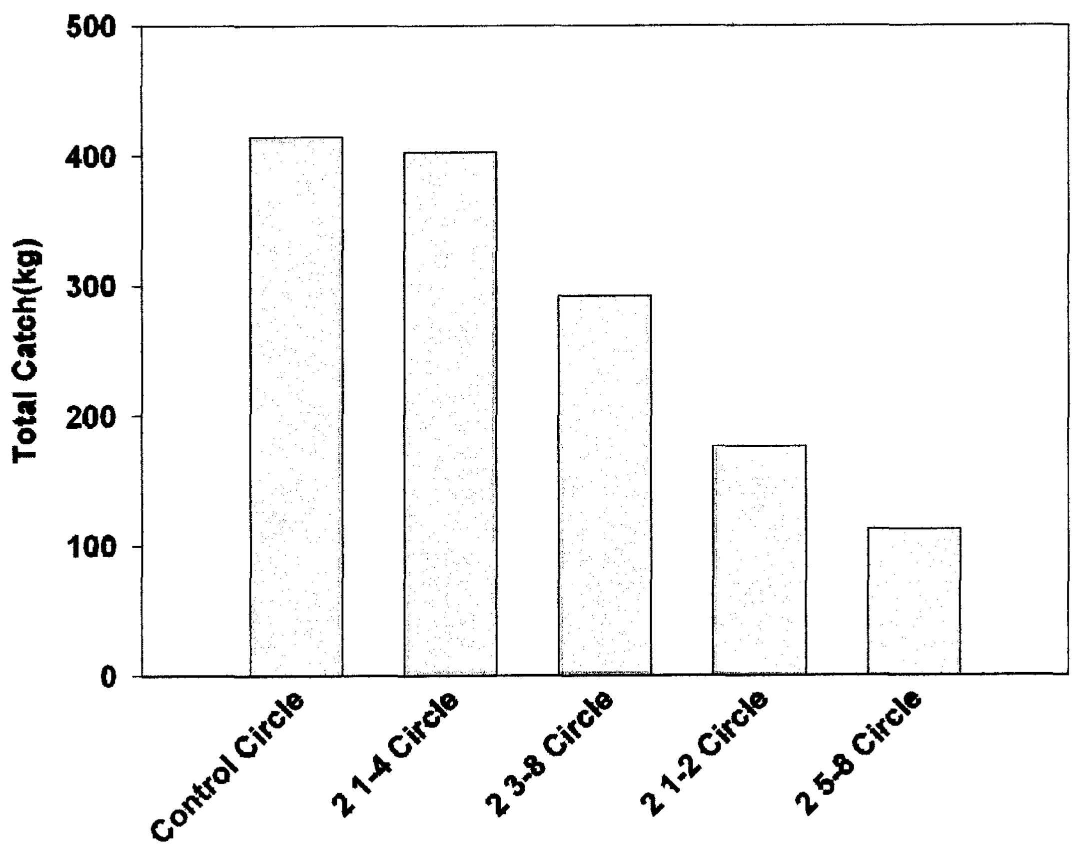
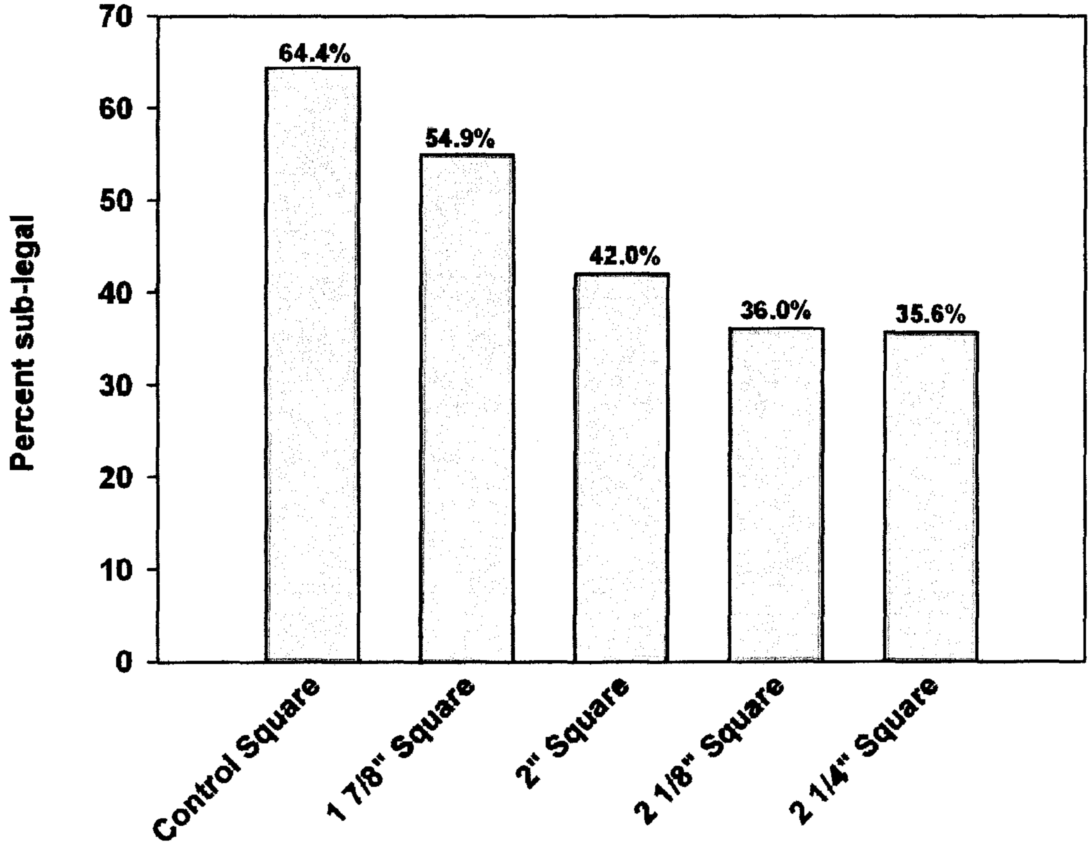

500
400
300
200
100
0
Total Catch(kg)
Control Circle
2 1-4 Circle
2 3-8 Circle
2 1-2 Circle
2 5-8 Circle

Figure 4

Percentage of sub-legal (less than 28 cm total length) black sea bass (by number) in traps with varying sizes and shapes of escape vents.


70
60
50
40
30
20
10
0
Percent sub-legal
64.4%
54.9%
42.0%
36.0%
35.6%
Control Square
1 7/8" Square
2" Square
2 1/8" Square
2 1/4" Square

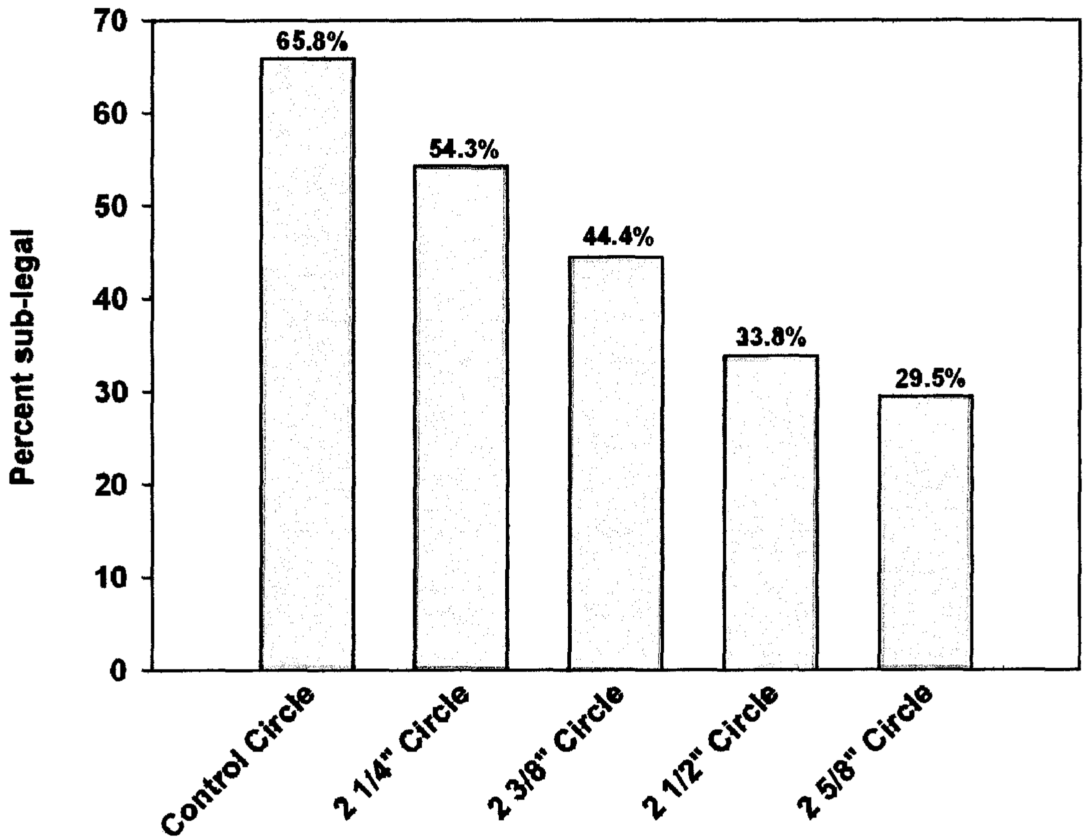

70
60
50
40
30
20
10
0
Percent sub-legal
65.8%
54.3%
44.4%
33.8%
29.5%
Control Circle
2 1/4" Circle
2 3/8" Circle
2 1/2" Circle
2 5/8" Circle

Figure 5

Length frequency distributions for black sea bass captured in traps equipped with varying sizes of square escape vents compared to a control trap (no escape vent). The vertical line represents the minimum legal size of 28 cm.

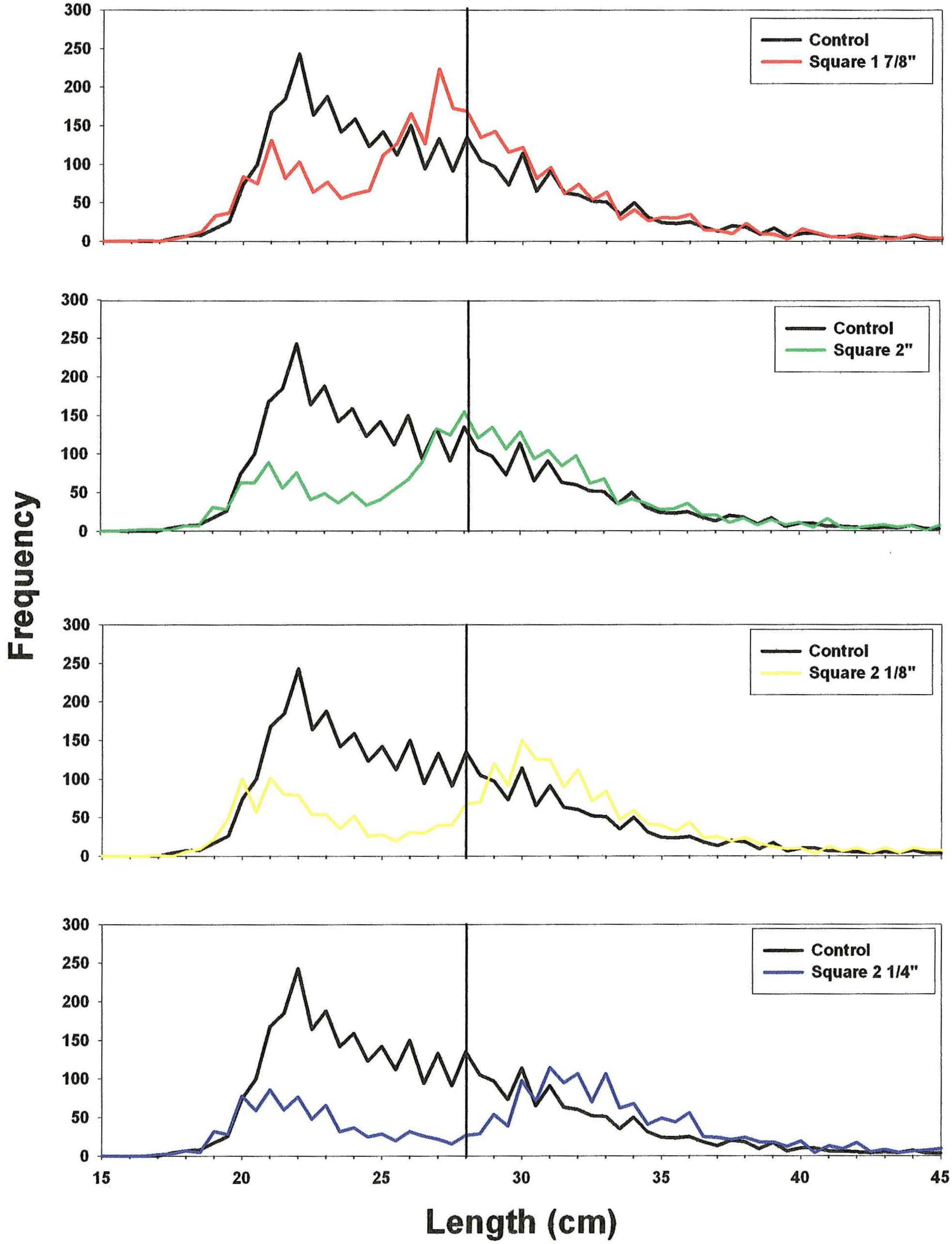

Frequency
Length (cm)
Control
Square 1 7/8"
Control
Square 2"
Control
Square 2 1/8"
Control
Square 2 1/4"
0
50
100
150
200
250
300
15
20
25
30
35
40
45

Figure 6

Length frequency distributions for black sea bass captured in traps equipped with varying sizes of circular escape vents compared to a control trap (no escape vent). The vertical line represents the minimum legal size of 28 cm.

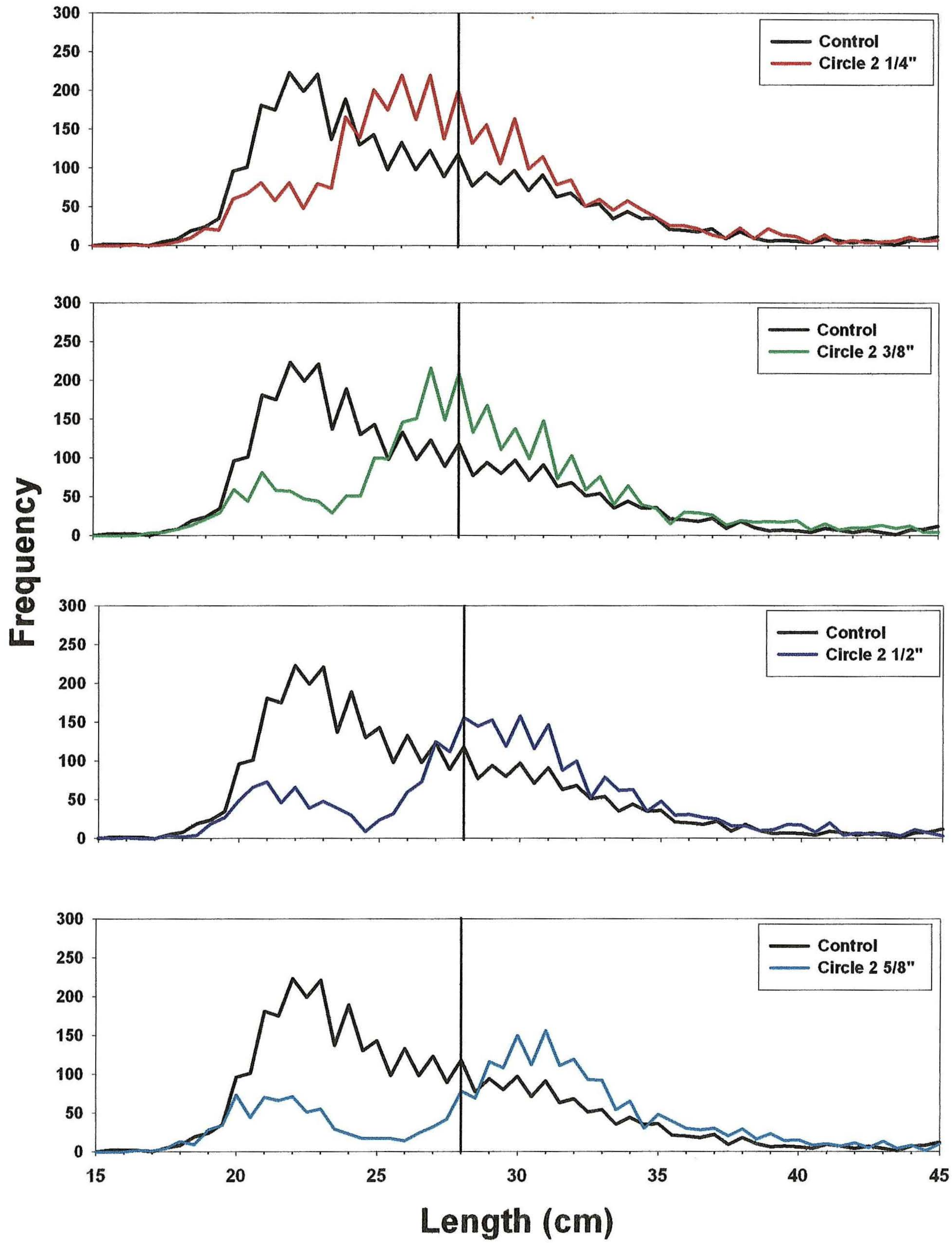
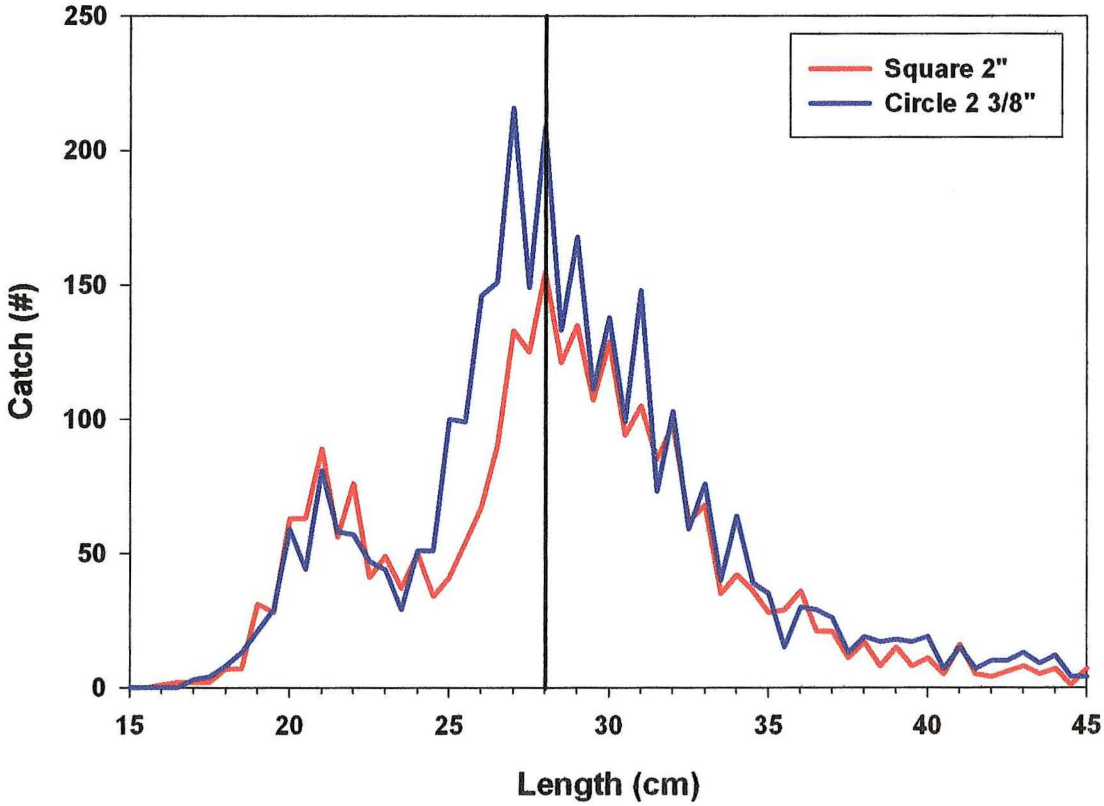

Control
Circle 2 1/4"
Control
Circle 2 3/8"
Control
Circle 2 1/2"
Control
Circle 2 5/8"
Frequency
Length (cm)
300
250
200
150
100
50
0
15
20
25
30
35
40
45

Figure 7

Length frequency distributions for black sea bass captured in traps equipped with the currently legal escape vents (2.0" square and 2 3/8" circle). The vertical line represents the minimum legal size of 28 cm.



Square 2"
Circle 2 3/8"
Catch (#)
250
200
150
100
50
0
15
20
25
30
35
40
45
Length (cm)

Figure 8

Proportion of sea bass retained in traps equipped with varying sizes of square escape vents relative to the control. The vertical reference line represents the current minimum legal size. The horizontal reference line represents the level where the experimental and control traps were equivalent

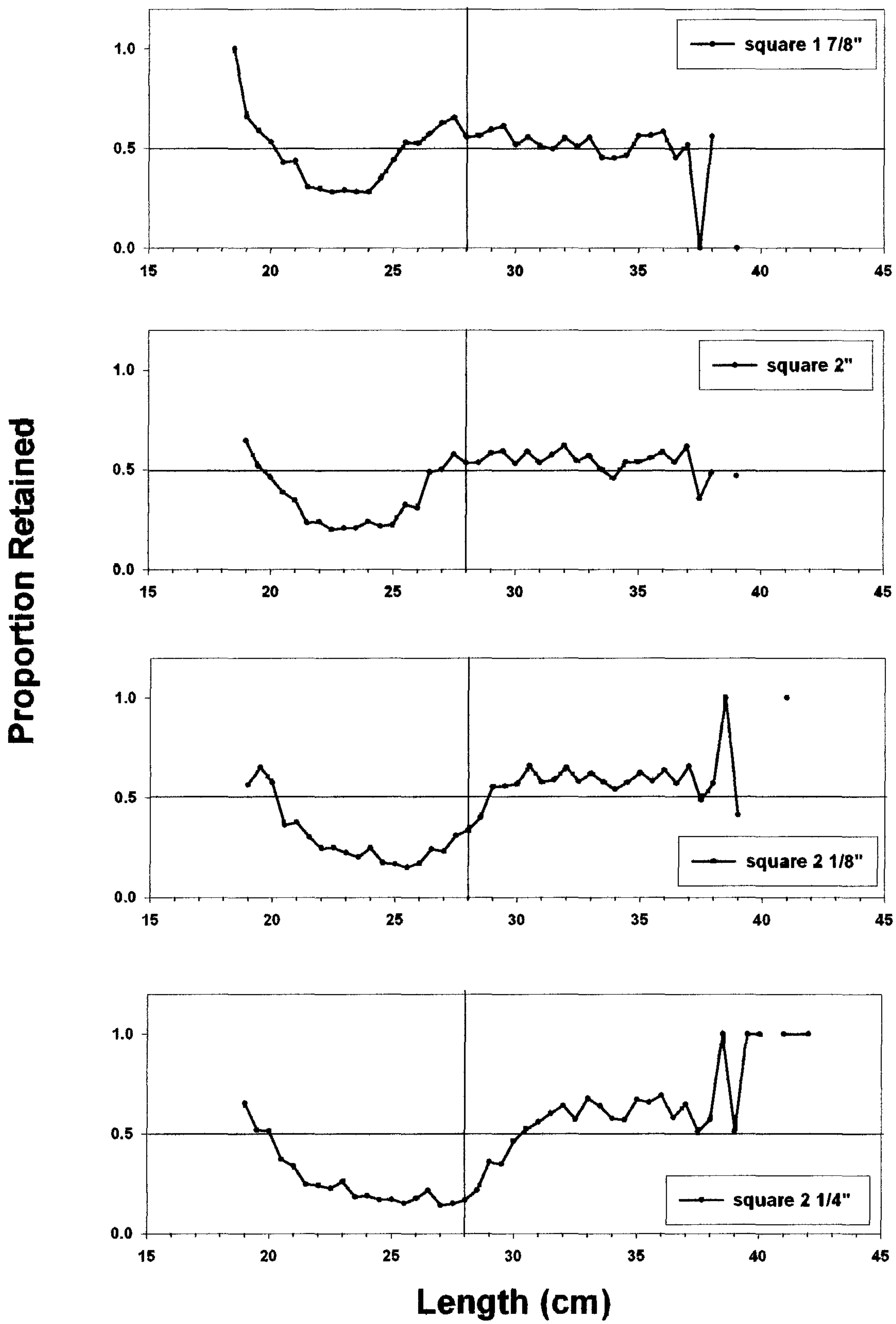
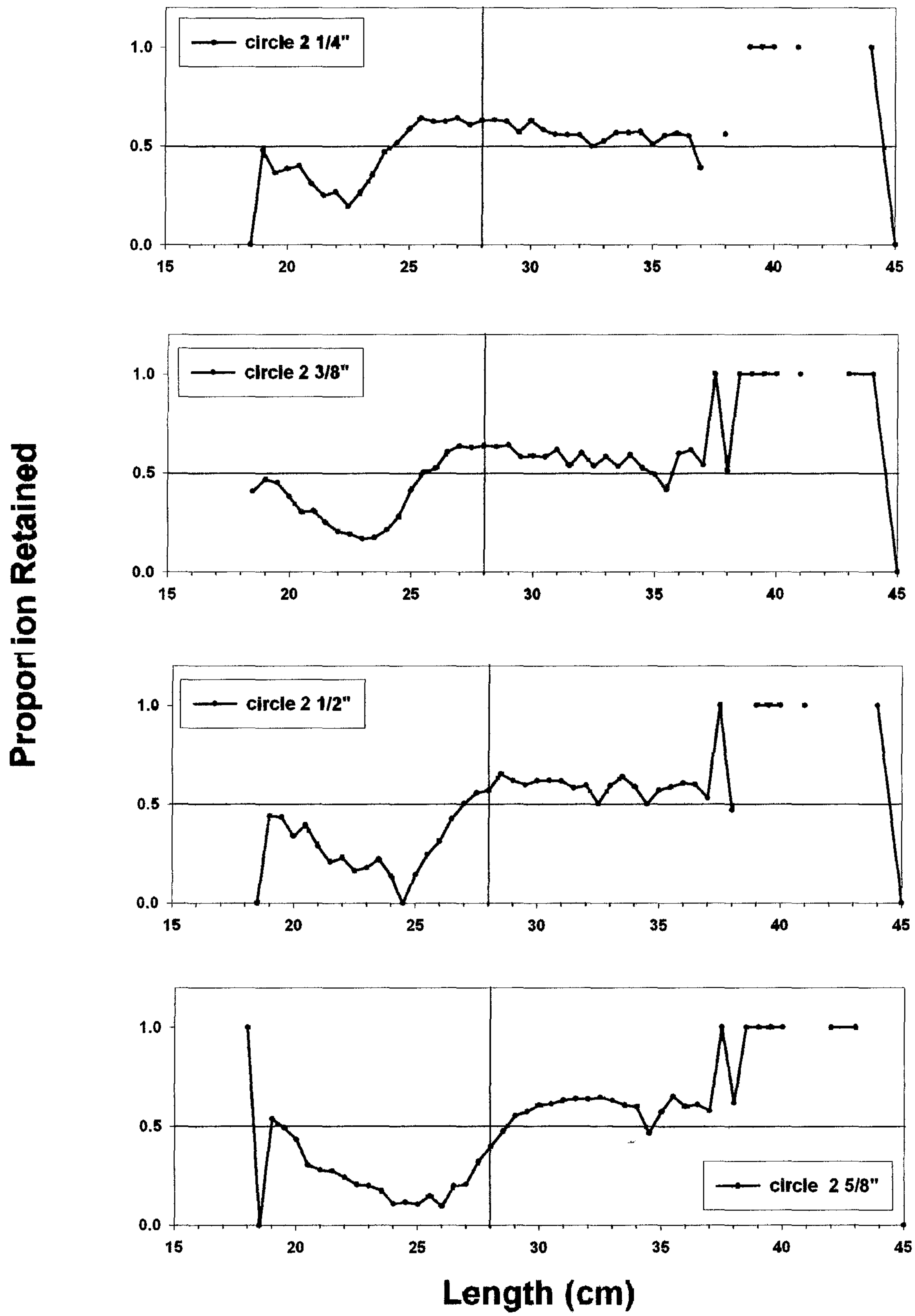

square 1 7/8"
square 2"
square 2 1/8"
square 2 1/4"
Proportion Retained
Length (cm)
0.0
0.5
1.0
15
20
25
30
35
40
45

Figure 9

Proportion of sea bass retained in traps equipped with varying sizes of circular escape vents relative to the control. The vertical reference line represents the current minimum legal size. The horizontal reference line represents the level where the experimental and control traps were equivalent



circle 2 1/4"
circle 2 3/8"
circle 2 1/2"
circle 2 5/8"
1.0
0.5
0.0
15
20
25
30
35
40
45
Proportion Retained
Length (cm)

Table 11
Finfish and invertebrate bycatch

Common Name	Scientific name	Number Caught
Jonah Crab	*Cancer borealis*	674
Conger Eel	*Conger oceanicus*	496
Octopus uncl.	*Octopoda*	345
Tautog	*Tautoga onitis*	288
Scup	*Stenotomus chrysops*	285
Gray Triggerfish	*Balistes capriscus*	94
Red hake	*Urophycis chuss*	52
American Lobster	*Homarus americanus*	27
Pigfish	*Orthopristis chrysoptera*	26
Summer Flounder	*Paralicthyes dentatus*	18
Spider Crab uncl.	*Majidae*	7
Atlantic Croaker	*Micropogonias undulatus*	5
Bluefish	*Pomatomus salatrix*	4
Longhorn Sculpin	*Hemitripterus americanus*	4
Armored Searobin	*Peristedion miniatum*	3
Spiny Dogfish	*Squalus acanthias*	1
Channeled whelk	*Busycotypus canaliculatus*	1
Atlantic Spadefish	*Chaetodipterus faber*	1